An Ultrasonic Blind Guidance System for Street Crossings

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Abstract. This paper addresses the technical feasibility of a guidance system based on ultrasonic sensors to aid visually impaired people to cross a road easily and safely. A computer processes ultrasonic signals emitted by a transmitter, which is carried by the impaired user, and provides real-time information on the direction and distance to keep user on the correct track. Instead of time of flight, the system estimates user position by the order of received ultrasonic signals at multiple receivers. Experimental results are presented to discuss feasibility of this method.

Keywords: guidance system, ultrasonic sensor, cross-correlation.

1 Introduction

There are many researches worldwide looking into many forms of travel aid for visually impaired people. These involve technologies like GPS, sonic or ultrasonic signals and or even advance image processing systems [1][2][3]. In comparison to other technologies many blind guidance systems use ultrasound because of its immunity to the environmental noise. Another reason why ultrasonic is popular is that the technology is relatively inexpensive, and also ultrasound emitters and detectors are small enough to be carried without the need for complex circuitry. Salah et al. use two ultrasonic sensors mounted on the user's shoulders and another one integrated into the white cane to perform obstacle detection. Also there have been many devices developed including the Russell Path sounder, AFBs computerized travel aid, or the MOWAT sensor, some of the first ultrasonic devices to be developed.

In Japan and particularly in Tokyo, bumpy yellow color tiles are installed along sidewalks. It functions as a Braille to guide blind when walking along the street. Typically tiles with round bumps indicate end of the pad or intersection or step, and tiles with longer bumps indicate direction. One major problem however, is that these tiles are not laid on street crossings, which makes it difficult to a blind to cross the street without any help. There exists some audible sounds that inform status of traffic light, but there are no devices to inform correct direction to the user. Current paper looks for the technical feasibility of an ultrasonic system to cover this lack for a safe and easy navigation across the street. In the next section we will discuss about the theory followed by experimental results and conclusions.

K. Miesenberger et al. (Eds.): ICCHP 2010, Part II, LNCS 6180, pp. 235–238, 2010.

There are different combinations in which ultrasound sensors are used. Some use portable transmitters, other use portable receivers, and some other use a combination of both. Transmitter site needs simple system as fix circuit, otherwise receiver site need comparatively complex system as computer. A system in which user carries transmitter and complex system is installed on fix site is adopted by virtue of user system compactness. User also might to carry an FM receiver system for getting position error information transmitted from fix site.

2 The Theory

The basic concept of the system is shown in Fig. 1. The straight line on the center of zebra pattern, starting from point *S* and ending at point *E* is the guidance route. On the opposite side of the street, three ultrasonic receivers R_1, R_2 and R_3 are arranged with equal distance *d* on the axis perpendicular to *SE* line. The transmitter circuit carried by the user at point $T(x,y)$ emits ultrasonic waves, which travel through the air and reach to R_1, R_2 and R_3 at three different times t_1, t_2 and t_3 respectively.

Assuming that the flight speed of ultrasonic waves is equal in all directions, the time of flight t1, t2 and t3 will represent the distance of user at point T to three receivers R_1, R_2 and R_3. According to Fig. 1, the distance from user at point $T(x,y)$ to these three receivers, labeled as d_1, d_2 and d_3 respectively, can be represented by:

$$d_1 = r_1 \;. \tag{1}$$

$$d_2 = r_1 + r_2 \;. \tag{2}$$

$$d_3 = r_1 + r_3 \;. \tag{3}$$

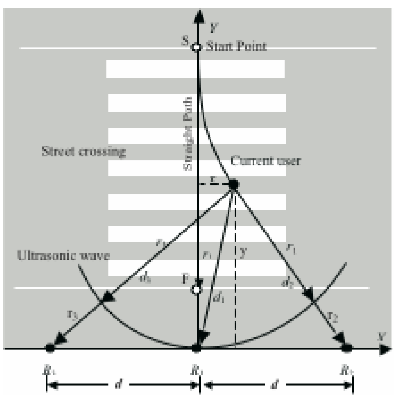

Fig. 1. Concept of the introduced system

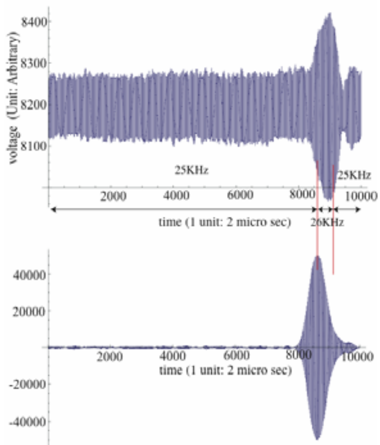

Fig. 2. Received signal and cross-correlation processing result

where r_2 and r_3 are calculated later by measurement of time of flight of ultrasonic waves. The x and y coordinates of transmitter T can be obtained by solving following three equations:

$$\begin{aligned} &x^2 + y^2 - r_1^2 = 0 . \\ &(x-d)^2 + y^2 - (r_1 + r_2)^2 = 0 . \\ &(x+d)^2 + y^2 - (r_1 + r_3)^2 = 0 . \end{aligned} \tag{4}$$

From (4) x and y will be written as:

$$x = \frac{(r_3 - r_2)(r_2 r_3 + d^2)}{2d(r_2 + r_3)} . \tag{5}$$

$$y = \frac{(r_3^2 - d^2)(r_2^2 - d^2)[4d^2 - (r_3 - r_2)^2)]}{2d(r_2 + r_3)} . \tag{6}$$

In (5) and (6), r_2 and r_3 can be calculated as:

$$r_2 = V \cdot \Delta t_{R2R1} . \tag{7}$$

$$r_3 = V \cdot \Delta t_{R3R1} . \tag{8}$$

where V indicates the velocity of ultrasonic waves, Δt_{R2R1} corresponds to the time delay of received signal at sensor R2 in respect to sensor R1, and Δt_{R3R1} corresponds to the time delay of received signal at sensor R_3 in respect to sensor R_1.

3 Experimental Result and Remarks

Resonance type ultrasonic transmitter emits 16 burst pulses at 50 Hz. In burst mode, Sensor dynamics make amplitude of initial rising few waves small compared with successive waves. Small amplitude make small contribution in cross-correlation processing, therefore peak position of cross-correlation which is arrival time of ultrasonic wave, have tendency to shift by few waves. The ultrasonic transmitter pulsates contiguously in order to improve rising property, in burst period by resonance frequency, in idle period by 1 KHz off from resonance frequency.

A 2 GHz PC/AT computer acquires receiver signals via a high speed 1MHz A/D convertor. It then performs signal enhancement on digitized signals and sends the guidance information through FM radio transmission back to the users. Using above mentioned hardware, some test results are shown in Fig. 3 and Fig. 4.

Fig. 3 shows raw position data obtained by the system for nine fixed user locations. No noise cancelling is used in this graph. Positions calculated by the system are shown as cluster of black solid circles.

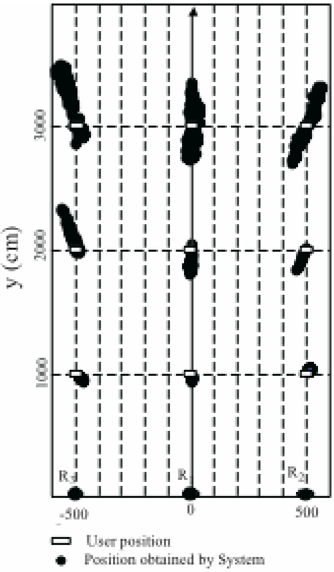

Fig. 3. Stationary test result

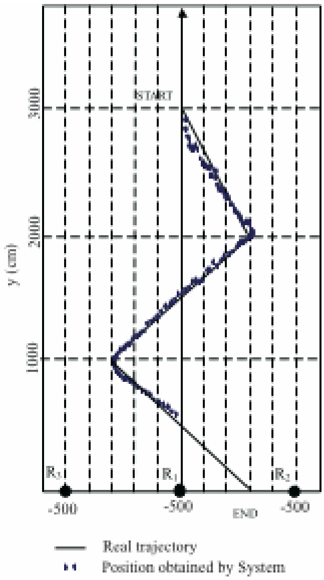

Fig. 4. Motion test result

Fig .4 demonstrated the results when user is in motion. Here, user starts from the start point and after walking along the zigzag path and reaches to the end point and shows the results after data processing like averaging and noise cancelling. Average is calculated over each 10 incoming data.

In next stage, megaphone will be used for amplifying received signal, though reducing detect angle. Five megaphones (two and three in two line) are installed for making detect angle wide as 75 degree. Each sensor signal installed in each megaphone will be processed by distributed dsPIC controller to detect most reliable signal.

References

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